(12) UK Patent Application (19) GB (11) 2 281 398 (13) A

(43) Date of A Publication 01.03.1995

(21) Application No 9421617.3

(22) Date of Filing 05.08.1991

Date Lodged 26.10.1994

(30) Priority Data
(31) 03090685 (32) 22.04.1991 (33) JP
03121291 27.05.1991

(62) Derived from Application No. 9116817.9 under Section 15(4) of the Patents Act 1977

(51) INT CL[6]
G01N 27/90

(52) UK CL (Edition N)
G1N N19B2C N19B4 N19F7E1
U1S S1884

(56) Documents Cited
GB 2129140 A GB 1403734 A US 4849693 A

(58) Field of Search
UK CL (Edition M) G1N NCDC NCDE NCDL NCDN
INT CL[5] G01N

(71) Applicant(s)
Tokyo Gas Co. Ltd

(Incorporated in Japan)

1-5-20 Kaigan, Minato-ku, Tokyo, Japan

CXR Co. Ltd.

(Incorporated in Japan)

2-4-10, Sanjoh,, Kure-shi, Hiroshima-ken, Japan

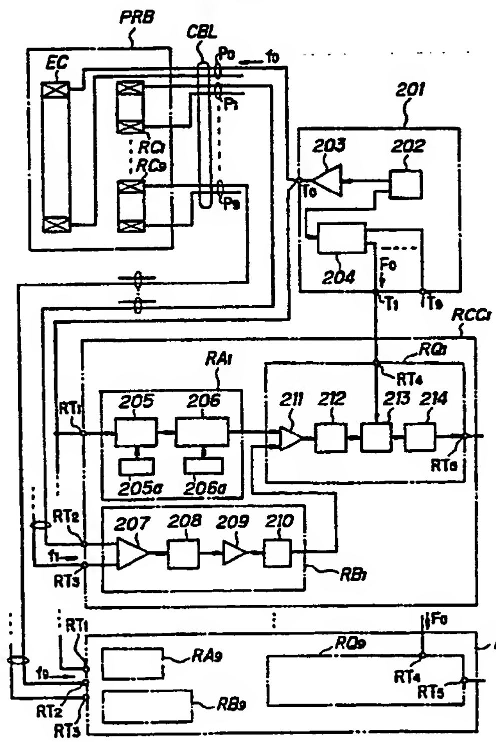
(72) Inventor(s)
Yasuharu Hosohara
Kiwamu Suzuki
Shigeru Fujiwara
Toshihide Kawabe

(74) Agent and/or Address for Service
Withers & Rogers
4 Dyer's Buildings, Holborn, LONDON, EC1N 2JT, United Kingdom

(54) Eddy current flaw detector

(57) A flaw detector for metal material which can check pipelines by means of the remote field eddy current method comprises an exciting coil EC and one or more receiving coils RC1 - RC9. The exciting coil is fed with a.c. from a reference source 202, the same signal being fed to an attenuator 205 and phase shifter 206. The signal picked up in each receiving coil is filtered (208, 210) and added to the phase shifted reference signal by adder 211. The output from the adder is passed via a waveform shaping circuit 212 to a phase comparator 213 which also receives a reference signal from the source 202. The comparator output is passed to a flaw detection signal generator 214.

FIG.2



GB 2 281 398 A

FIG. 1

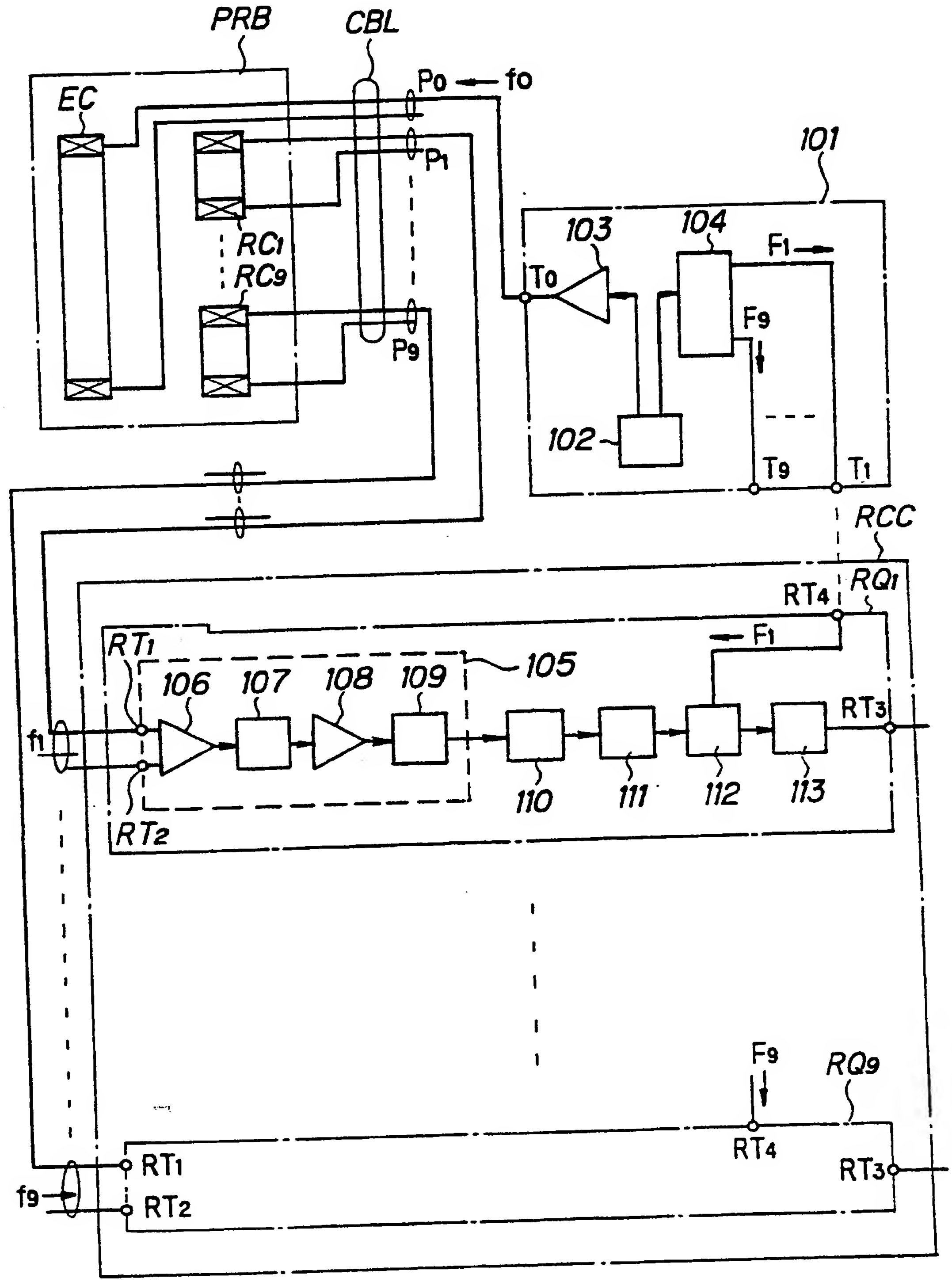
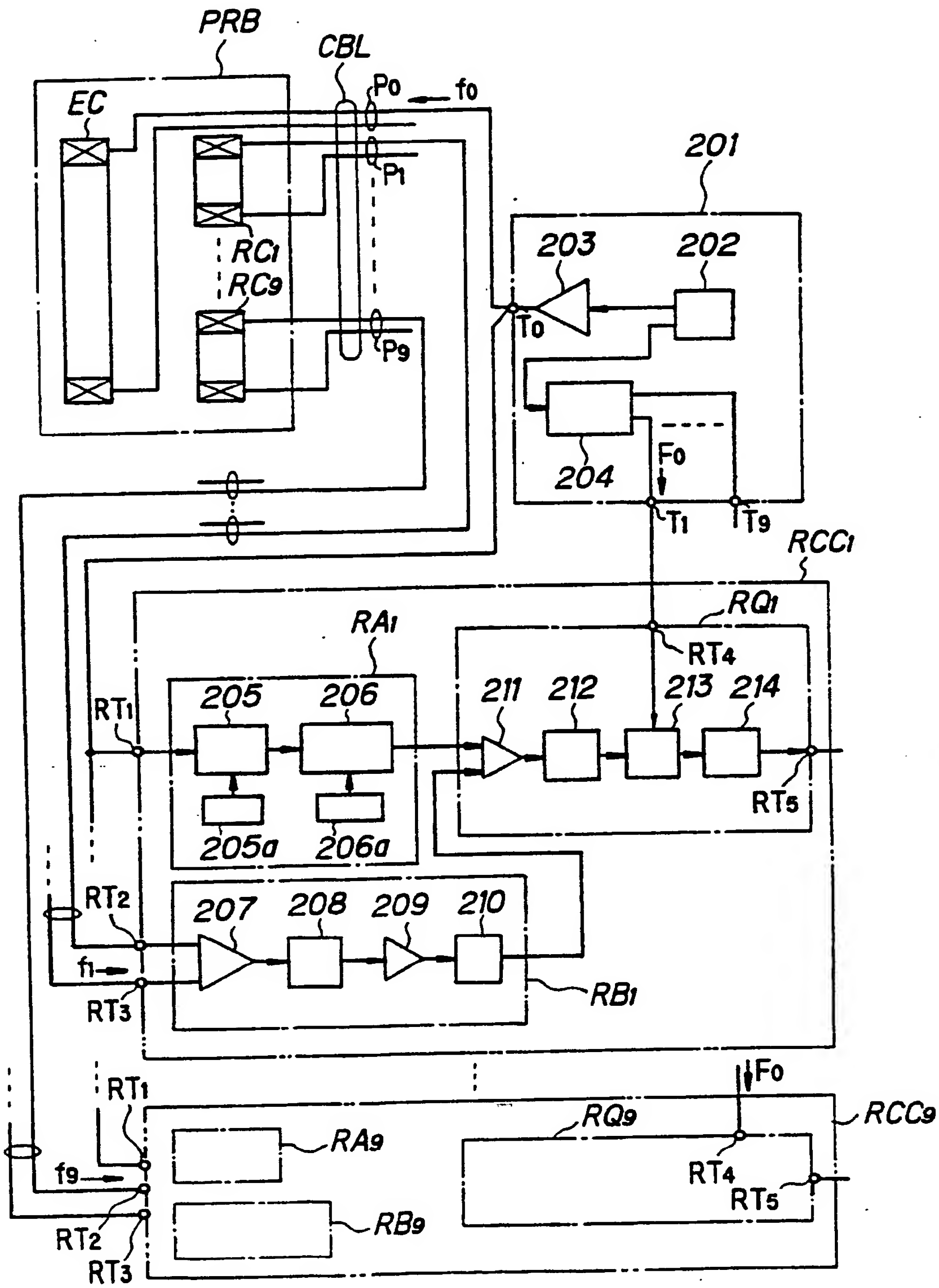

PRB
CBL
EC
P0
f0
P1
RC1
RC9
P9
101
103
104
F1
T0
F9
102
T9
T1
RCC
RT4
RQ1
F1
RT1
105
106
107
108
109
f1
RT3
110
111
112
113
RT2
F9
RQ9
RT4
RT1
RT3
f9
RT2

FIG.2



PRB
CBL
EC
Po
f0
P1
RC1
RC9
P9
201
203
202
T0
204
F0
T1
T9
RCC1
RQ1
RA1
RT4
RT1
205
206
211
212
213
214
205a
206a
RT5
RT2
207
208
209
210
f1
RT3
RB1
RT1
F0
RCC9
RQ9
RA9
f9
RT4
RT5
RT2
RB9
RT3

FIG. 3

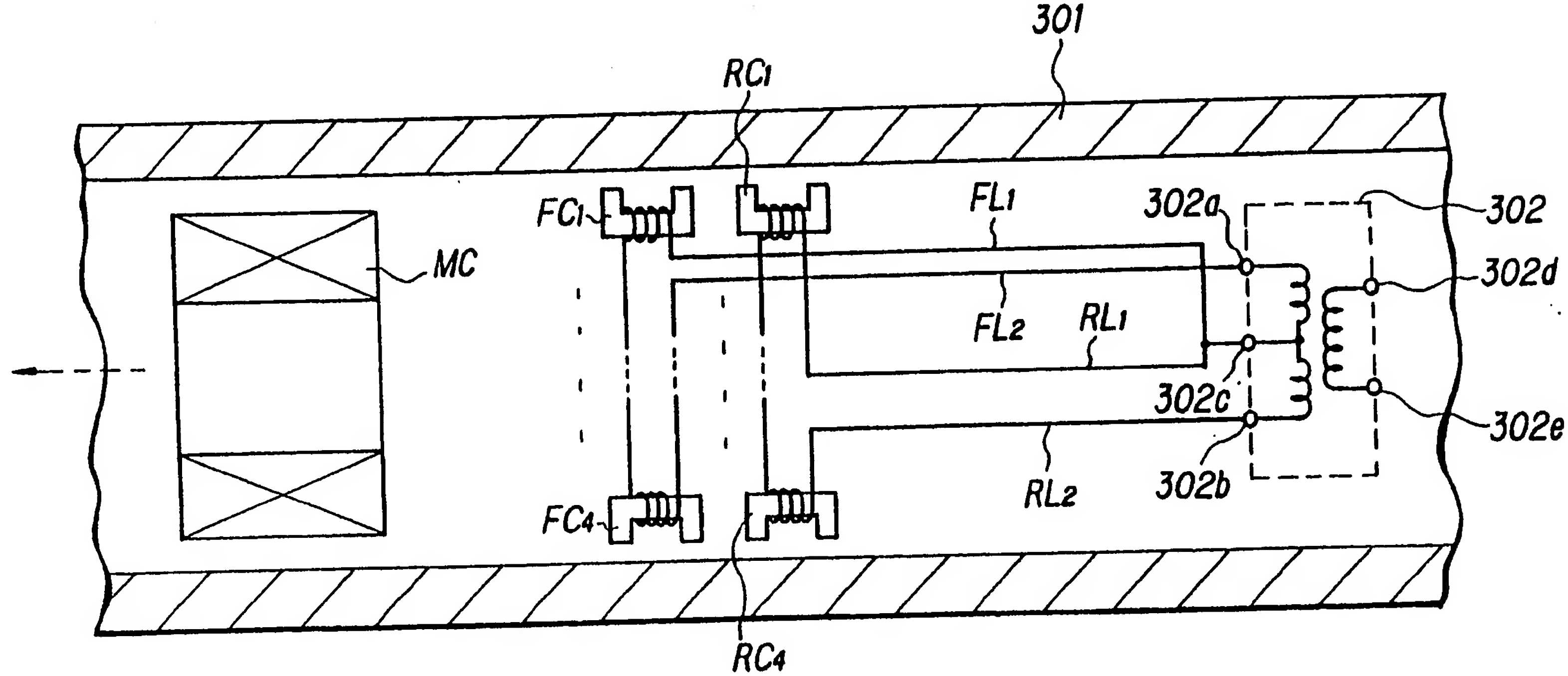

301
RC1
FC1
MC
FL1
FL2
RL1
302a
302
302d
302c
302e
302b
RL2
FC4
RC4

FIG.4

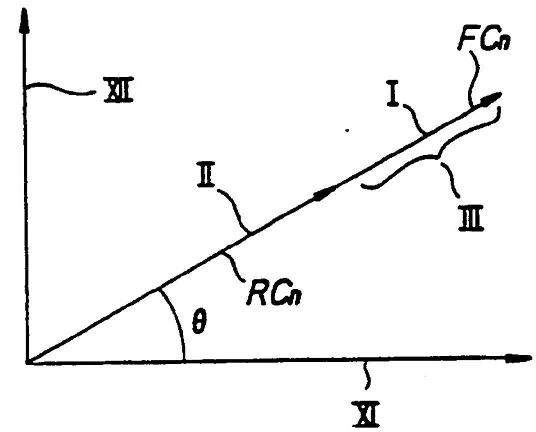


FIG.5

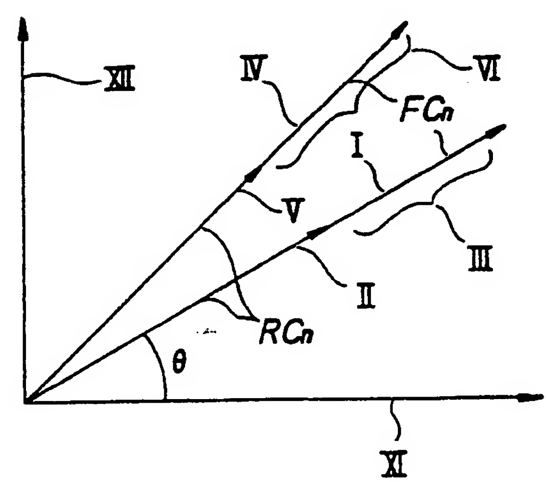


FIG.6

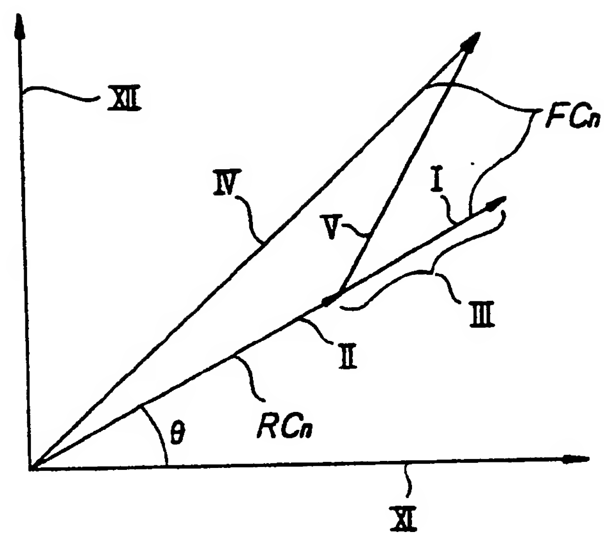
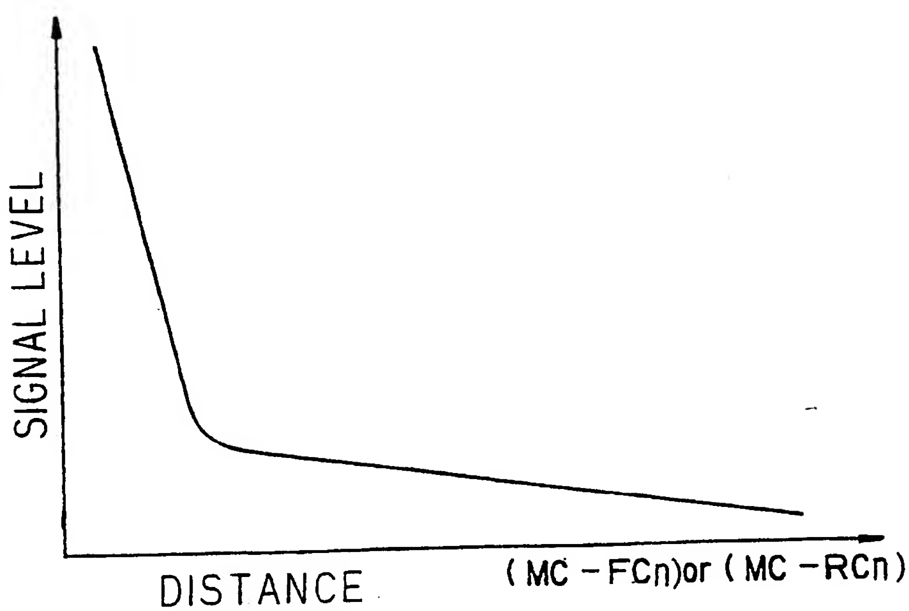

XII
FCn
IV
I
V
III
II
θ
RCn
XI

FIG.7


SIGNAL LEVEL
DISTANCE
(MC −FCn)or (MC −RCn)

2281398

FLAW DETECTOR FOR METAL MATERIAL

Field of the Invention

The present invention relates to a flaw detector for metal material which can maintain and manage pipelines such as a buried gas pipeline, a chemical plant pipeline and a heat exchanger pipeline by the remote field eddy current method, and a remote field eddy current sensor which is suitable for such flaw detector.

Background of the Invention

When detecting flaws of metal materials such as pipelines by using the remote field eddy current method, a remote field eddy current sensor connected to a cable for transmitting signal is inserted into the pipeline and exciting voltage is supplied to the sensor. The sensor includes an exciting coil and one or more receiving coil spaced from the sensor to the longitudinal direction of the pipeline at a predetermined distance being two times longer than a diameter of the pipeline. Relatively low frequency such as from tens Hz to hundreds Hz is used as the applied exciting signal and such voltage from several V to tens V is used as the exciting voltage.

Electromagnetic wave generated by the exciting signal is separated into two groups; one passes through a thickness of the pipeline to be tested and the other transmits in the pileline. The latter is rapidly attenuated and hardly transmitted, since, if the pipleine is considered to be a wave guide, it has far lower frequency than cut off frequency. On the other side, the former called to be indirect transmitting wave, transmits along the pipeline outside thereof and is gradually attenuated. At the same time, a part of the former wave passes again through the thickness of the pipeline, permeates into the pipeline and is received by the receiving coil.

The received signal detected by the receiving coil is very subtle (from several micro V to tens Micro V), since it passes through the pipeline twice, and the phase thereof is changed by the skin effect by passing through the thickness of the pipeline. In the remote field eddy current method, the phase change having good linearity to the thickness of the pipeline is sometimes used as information.

In the remote field eddy current method, when the eddy current sensor including the exciting coil and the receiving coil is inserted into the pipeline to be tested and progressed at a constant velocity, the amplitude of the received signal is changed and phase detected flaw data is mixed with phase detection noise, since dielectric constant of the pipeline to be tested is not uniform and the eddy current sensor vibrates by the progressing movement. Thus, the detected flaw data may be converted to abnormal one. Further, when another type of the eddy current sensor wherein a plurality of the receiving coil are arranged annularly in the inner wall of the pipeline, it is difficult to make accurate diagnosis of the pipeline, since the abnormal flaw data is accumulated.

The remote field eddy current method can be classified into two types; a absolute type in which a plurality of receiving coils are arranged concentricallay at the rear of a excitng coil and a differential type which includes a front group of the receiving coils concentrically arranged and a rear group of the receiving coils arranged at the rear of the front group. In the absolute type, number of turns of each coil of the group of the receiving coils are same, respectively, and a plurality of receiving coils are connected with a measuring device by required number of pair cables for producing sensor signal. On the other hand, in the differential type, number of turns of each

coil of the front group and the rear group of the receiving coils are all same, respectively, and the front coil and the rear coil are differentially connected to each other and are connected with a measuring device by required number of pair cables.

While, in the absolute type sensor, the received signal can be always received in a part having none of flaw, in the differential type sensor, the received signal can be hardly received except in a part having changed shape such as a local flaw because of the differential connection. This phenomenon also can be found when using another type of receiving coil (normal direction coil) in which magnetic path by the remote field eddy current is arranged normal to the axis of the exciting coil.

When using the group of receiving coils comprising the differential type coil or the normal direction coil in the remote field eddy current method, in the normal part of material to be tested, it is difficult to get sufficient received signal in order to make stable phase detection and the phase detected flaw data is mixed with noise. Thus, the flaw data may be converted to the abnormal flaw data.

Further, when using the remote field eddy current sensor in which a plurality of the receiving coils are arranged annularly in the inner wall of the pipeline, it is difficult to make accurate diagnosis of the pipleine bacause of the accumulation of abnormal flaw data.

In the differential type sensor, number of turns of each receiving coil of the front group and the rear group of the receiving coils are all same, respectively, and required number of coils are in parallel or in serial connected in the front group or the rear group, and the front coils and the rear coils are differentially connected to each other and connected with the measuring device by required number of pair

cables.

In the absolute type of the remote field eddy current sensor having the above mentioned construction, while stable diagnosis can be made because relatively high level sensor signal can be provided and the sensor is suitable for the detection of gradually progressing flaw part FW of the pipeline to be tested, however, the detecting sensibility to the local flaw part FS is low and frequently the sensor cannot detect small local flaw part FS. On the other hand, in the differential type of the remote field eddy current sensor, while the flaw part can be detected by the level difference between the front group of the receiving coils and the rear group of the receiving coils and the sensor has advantage to the local flaw part FS because of its high sensibility, however, it is hard to get the difference signal from the gradually proressing flaw part. Further, it is hard to make stable phase detection because the differential signal is too small.

In the both type of the remote field eddy current sensor, since measurement is performed not only by strength and weakness of the sensor signal level, but also by computing width or depth of the flaw by phase delay characteristics of acquired sensor signal, it is important to get stability of the phase detection.

<u>Summary of the Invention</u>

The first object of the present invention is to remove influences of noise of phase detection.

The second object of the present invention is to provide a flaw detector for metal material which can decrease phase detecting noise by getting stability of received level by automatically adjusting received signal produced by the receiving coil to a predetermined level and which can improve S/N ratio of flaw data by such decrease of phase detecting noise.

The third object of the present invention is to

provide a flaw detector for metal material which can prevent the accumulation of the abnormal flaw data by phase detecting noise included in many flaw data, when using the remote field eddy current sensor including a plurality of receiving coils.

The forth object of the present invention is to provide a flaw detector for metal material which can prevent generation of abnormal flaw data by overlaying the received signal produced by the receiving coil with AC signal having a predetermined phase and amplitude.

The fifth object of the present invention is to provide a flaw detector for metal material which can prevent accumulation of abnormal flaw data by phase detecting noise included in the flaw data by using the remote field eddy current sensor including a plurality of receiving coil arranged annularly in the inner wall of the pipeline.

The sixth object of the present invention is to provide a remote field eddy current sensor which is suitable for such a flaw detector for metal material that can produce sensor signal by which stable phase data to both of the gradually progressing flaw and the local flaw can be obtained by employing the construction in which number of turns of the front receiving coils are greater than that of the rear receiving coils.

A flaw detector for metal material according to the present invention comprises a reference signal generator means for generating reference signal; an exciting coil for receiivng an exciting signal having same phase as that of said reference signal to generate remote field eddy current in metal material to be tested: a receiving coil, spaced from said exciting coil at a predetermined distance, for receiving said remote field eddy current to generate received signal: an automatic amplitude adjustor means for adjusting the received signal provided from said receiving coil to a constant level;

and a flaw data generator means for comparing said received signal adjusted by said automatic amplitude adjusting means with said reference signal to generate flaw data.

Further, the flaw detector for metal material according to the present invention may comprise a plurality of said receiving coil, said automatic amplitude adjusting means and said detected flaw data generating means.

The exciting signal provided by the reference signal generator means is transmitted to the exciting coil. The received signal produced by the receiving coil is transmitted to the received signal processing module in a received signal circuit. Compare signal produced by a compare signal generator means in the exciting signal producing means and transmitting to the received signal processing module, is phase-compared by a phase comparator and amplitude level of the received signal is automatically adjusted in AGC circuit. Thus, phase detecting noise included in the flaw data produced by the phase comparator is decreased and S/N ratio of the flaw data can be improved.

Further, a flaw detector for metal material according to the present invention comprises a reference signal generator means for generating reference signal; an exciting coil for receiving exciting signal having same phase as that of said reference signal to generate remote field eddy current in metal material to be tested; a receiving coil, spaced from said exciting coil at a predetermined distance, for receiving said remote field eddy current to generate received signal; an AC generator means for generating constant level AC signal by phase-shifting said reference signal at a predetermined phase angle; a signal adder means for adding said AC signal provided by said AC signal generating means to said receiving signal; a detected

flaw data generating means for comparing said AC signal added by said adder means and said received signal with said reference signal to generate flaw data.

Further, the flaw detector for metal material according to the present invention may comprises a plurality of said receiving coils, said automatic amplitude adjusting means and said flaw data generating means.

When exciting signal is applied to the exciting coil of the remote field eddy current sensor, received signal is generated in the receiving coils. After in-phase noise of the received signal is removed by a differential amplifier of a received signal interface and high frequency component thereof is removed by a low pass filter, the received signal is supplied to the other input of the adder. On the other hand, the exciting signal supplied to the adding terminal of the added signal processing module is attenuated to a level determined by an amplitude setting means of the attenuator of an added signal generating module. Then, if phase angle is predetermined by a phase angle setting device in the phase shifter to for example 15 degree, added signal having 15 degree of phase angle delay is supplied to the one input of the received signal processing module.

Further, a remote field eddy current sensor according to the present invention comprises an exciting coil for generating remote field eddy current to metal material to be tested; a first receiving coil, spaced from said exciting coil at a predetermined distance, for receiving said remote field eddy current; a second receiving coil, spaced from said exciting coil at further distance than said predetermined distance, for receiving said remote field eddy current, number of turns of the second receiving coil is fewer than that of said first receiving coil. Therefore, stable phase data

to both of the gradually progressing flaw and local flaw can be obtained.

Description of the Drawings

Figure 1 is a block diagram of one embodiment of a flaw detector for metal material according to the present invention.

Figure 2 is a block diagram of another embodiment of a flaw detector for metal material according to the present invention.

Figure 3 is a block diagram of a remote field eddy current sensor according to the present invention.

Figure 4 is a signal vector diagram of a normal pipeline associated with Figure 1.

Figure 5 is a signal vector changing diagram of gradually progressing flaw associated with Figure 1.

Figure 6 is a signal vector changing diagram of local flaw associated with Figure 1.

Figure 7 is a characteristics diagram illustrating signal level to a distance between an exciting coil and a receiving coil.

Description of the Preferred Embodiment

Hereinafter, one embodiment of a flaw detector for metal material according to the present invention will be illustrated with reference to Figure 1.

As described in Figure 1, a flaw detector for metal material according to the present invention comprises an eddy current sensor PRB including a exciting coil EC and a plurality of receiving coils RCn (for the purpose of description, n is referred to as 1 to 9), an exciting signal generating circuit 101 including a reference signal generator 102, an exciting signal output amplifier 103 and a compare signal generating circuit 104 and a received signal circuit RCC including a plurality of the received signal processing modules RQ_1 to RQ_9. An exciting side terminal T_0 of the exciting signal producing circuit 101, receiving side

terminals RT_1 and RT_2 ... of the received signal processing modules RQ_1 to RQ_9 of the received signal circuit RCC are connected to pair cables P_0 to P_9 of cables CBL. Exciting signal f_0 produced by the pair cables P_0 is received in the exciting coil EC and received signal f_1 to f_9 is transmitted by the pair cables P_1 to P_9. If employing a special cable CBL wherein exciting signal having higher voltage than that of received signal F_1 to f_9, compare signal F_1 to F_9 may have same phase as the exciting signal f_0.

Each receiving terminal RT_1 to RT_2 of the received signal processing modules RQ_1 to RQ_9 of the received signal circuit RCC is connected to input side of a differential of a received signal interface 105. Output side of the differential amplifier is connected to input side an AGC circuit 110 through a low pass filter 107, a receiving amplifier 108 and a band pass filter 109. Homopolar noise generated in the pair cables. P_1 to P_9 is removed by the differential amplifier. High frequency component of the received signal f_1 to f_9 generated by the differential amplifier 106 is removed by the low pass filter 107. The received signal f_1 to f_9 whose high frequency component is removed by the low pass filter 107, is supplied to input side of the AGC circuit 110 through the band pass filter 109. After being converted to a predetermined level of amplitude by the AGC circuit 110, the received signal is supplied to a waveform shaper 111. Output side of the waveform shaper 111 is connected to one input side of a phase comparator 112. Another input side of the phase comparator 112. Another input side of the phase comparator 112 is connected to a receiving terminal RT_3 through a flaw detecting signal generating device 113.

Each receiving terminal RT_4... of the received signal processing modules RQ_1 to RQ_9 is connected to

exciting terminals T_1 to T_0 of the exciting signal generating circuit 101. Each phase comparator 112 of the received signal modules RQ_1 to RQ_9 compares received signal f_1 to f_9 supplied into one output side thereof with the compare signals F_1 to F_9 supplied into another input side thereof.

In the embodiment of the flaw detector having the above construction, since the amplitude level of the received signal f_1 to f_9 of output side of the band pass filter 109 are automatically adjusted to the predetermined level by the AGC circuit 110, even if magnetic permeability of a pipeline to be tested is not uniform, the level of the received signal supplied to the phase comparator 112 does not change. Thus, phase detection noise mixed into the flaw data generated from the phase comparator 112 may decrease and S/N ratio of the flaw detecting data may be improved by such decrease of the phase detection noise. If a plurality of receiving coils, the automatic amplitude adjusting means and the flaw data generator is provided, accumulation of abnormal flaw data caused by the phase detection noise included in the flaw data an be prevented.

Figure 2 is a block diagram of another embodiment of a flaw detector for metal material according to the present invention.

In the Figure 2, a flaw detector comprises a remote field eddy current sensor PRB including an exciting coil EC and a plurality of the receiving coils RCn (for convenience to illustrate, n is referred to as 1 to 9 and a differential coil may be used), an exciting signal generating circuit 201 including a reference signal generator 202, an exciting signal generating amplifier 203, a compare signal generating circuit 204, and received signal circuits RCC_1 to RCC_9 including received signal processing modules RQ_1 to RQ_9, added signal generating modules RA_1 to RA_9 and received

signal interfaces RB_1 to RB_9, respectively.

Output side of the reference signal generator 202 of the exciting signal generating circuit 201 is connected to the input side of the exciting signal amplifier 203 and output side of the exciting signal generating amplifier 203 is connected to a terminal T_o, respectively. The transmitting terminal T_o is connected to the exciting coil EC of the remote field eddy current sensor PRB through a pair cable P_o of the cable CBL. Each receiving coil RC_1 to RC_9 is connected to receiving terminals RT_2 and RT_3 of the received signal circuits RC_1 to RC_9 through pair cables P_1 to P_9 of the cable CBL. Said pair cable P_o receives the exciting signal f_o and the pair cables P_1 to P_9 transmit the transmitting signal F_1 to f_9. The transmitting terminal T_1 is connected to an adding to terminal RT_1 of the received signal circuits RCC_1 to RCC_9.

Output side of the reference signal generator 202 of the exciting signal generating circuit 201 is connected to input side of the compare signal generating circuit 204 and nine output sides of the reference signal generating circuit 204 are connected to the reference signal terminals T_1 to T_9. The reference signal terminals T_1 to T_9 are connected to a compare terminal RT_4 of the received signal circuits RCC_1 to RCC_9.

The added signal generating modules RA_1 to RA_9 include an attenuator 205, an amplitude setting device 205a, a phase shifter 206 and a phase angle setting device 206a. Input side of the attenuator 205 is connected to the adding terminal RT_1 and output side thereof is connected to input side of the phase shifter 206. Output side of the phase shifter 206 is connected to one input side of an adder 211, described latter, of the received signal processing modules RQ_1 to RQ_9.

Received signal interfaces RB_1 to RB_9 are connected to a differential amplifier 207, a low pass filter 208, a receiving amplifier 209 and a band pass filter 210, respectively. Output side of the differential amplifier 207 is connected to another input side of said adder 211 through the low pass filter 208, the receiving amplifier 209 and the band pass filter 210.

The receive signal processing modules RQ_1 to RQ_9 comprise the adder 211, a waveform shaping circuit 212, a phase comparator 213, a flaw data generating device 214. Each phase shifter 206 of the added signal generating modules RA_1 to RA_0 is connected to one input side of the adder 211 and each band pass filter 210 of the received signal interfaces RB_1 to RB_9 is connected to the other input side of the adder 211. The output side of the adder 211 is connected to a flaw data terminal RT_5 through the waveform shapig circuit 212, the phase comparator 213, the flaw detecting signal generating device 214. The compare signal terminals T_1 to T_9 of the exciting signal generating circuit 201 are connected to a comparing input side of the phase comparator 213 through each comparing terminal RT_4 of each module side of the received signal processing module RQ_1 to RQ_9.

In the flaw detector for metal material having the above construction illustrated in Figure 2, when exciting signal F_o is supplied to the exciting coil EC of the remote field eddy sensor PRB, received signal F_1 to F_9 is generated in the receiving coil RC_1 to RC_9. The received signal f_1 to f_9, whose in-phase noise is removed by the differential ampifier 207 and whose high frequency component is removed by the low pass filter 208, are supplied to another input side of the adder 211. On the other hand, the exciting signal f_o applied to the adding terminal RT_1 of the added

signal processing modules RC_1 to RCC_9 is attenuated to a level set in an amplitude setting device 205a of the attentuator 205 of the added signal generating modules RA_1 to RA_9. Then if, in the phase shifter 206, a phase angle is set to a predetermined phase angle, for example 15 degree, in a phase angle setting device 206a, added signal, whose phase angle is delayed by 15 degree, is transmitted to one input side of the received signal processing modules RQ_1 to RQ_9. In the adder 211, since the received signal f_o to f_9 generated in a pipeline to be tested is added with the added signal, phase noise is certainly removed by the adder 211 and the received signal f_o to f_9 having constant level is applied from the output side of the adder 211 to the phase comparator 213. Thus, in the phase comparator, stable phase detection can be performed. Since stable phase detection can be performed, normal flaw data is supplied to the flaw data terminal RT_5 and it can be prevented an error diagnosis of shape, depth and place of the flaw part caused by accumulation of the abnormal flaw data by the noise.

Figure 3 illustrates another embodiment of a remote field eddy current sensor according to the present invention.

In the Figure 3, MC is an exciting coil. Forward receiving coils FCn (n is 1 to 6) are provided at the rear of an exciting coil MC in a predetermined distance (about two times further than pipeline diameter). The forward received coils FC_1 to FC_6 are provide to be spaced from each other in 60 degree with reference to a pipeline to be tested 301. That is, the forward receiving coil FC_1 is provided in a direction of twelve o'clock, FC_2 is provided in a direction of two o'clock ... FC_3 is provide in a direction of 10 o'clock each of the forward receiving coils FC_1 to

FC_6 is connected in serial and cables FL_1 and FL_2 drawn therefrom are connected to terminals 302c and 302a of a differential coils 302. Further, rear receiving coils RC_n(n is 1 to 6) are provided at the rear of the forward receiving coils FC_1 to FC_6. Number of turns of the rear coils RC_1 to RC_6 are fewer than that of the forward receiving coils FC_1 to FC_6. The rear coils RC_1 to RC_6 are provided in same direction as that of the forward receiving coils FC_1 to FC_6, respectively. That is, the rear receiving coils RC_1 are provided in the direction of the 12 o'clock.

The rear receiving coils RC_1 and RC_6 are connected in serial and are connected to terminals 302c and 302b of the differential coil 302 through cables RL_1 and RL_2.

One end of the rear receiving coils FCn and one end of the forward receiving coils FCn are connected to each other and another end of the rear and forward receiving coils are drawn, respectively to construct a differential wire bound between the forward receiving coils FCn and the rear receiving coils RCn. In this wire bound construction, the differential coil can be eliminated.

When the remote field eddy current sensor having the above construction is provided to normal part of the pipeline, a signal vector I (in this description, I, II.... is referred to as vector) by the forward receiving coils FCn and same phase R as that of a signal vector II by the rear receiving coils RCn, since both coils are provided in adjacent position. Vector III is a differential vector by the differential wire bound. Vector III equals I substrated by II and has the phase R, since their directions are same. When the signal vector III is detected by reference signal vector XI, phase data R of the normal part can be obtained. Traditionally, since vector III is small value in the

equation of I - II = III, the phase detection becomes unstable and stable data cannot be obtained. In the remote field eddy current sensor according to the present invention, however, since not only signal level of the forward receiving coils FCn is higher than that of the rear receiving coils RCn whose distance from the exciting coil MC is further than that of the forward receiving coils FCn, but also number of turns of the forward receiving coils FCn is greater than that of the rear receiving coil. Thus, additional signal level is added and enough level of the differential vector III can be obtained to perform stable phase detection.

Figure 5 illustrates change of the signal vectors as to a large gradually flaw progressing part FW. In the drawing, signal vector I is signal vector of a normal part by the forward receiving coils Fcn, II is signal vector of the normal part by the rear receiving coils FCn and III is signal vector of the normal part by the differential wire bound. Since the gradually flaw progressing part FW ranges wide area, both of the forward receiving coils and the rear receiving coils are included in the flaw part and both signal vectors change simultaneously. Further, IV is signal vector of a gradually flaw progressing part by the forward receiving coils FCn, V is signal vector of the gradually flaw progressing part by the rear receiving coils RCn and VI is signal vector of the gradually flaw progressing part by the differential wire bound. VI is included in the gradually flaw progressing part FW and the gradually flaw part FW can be detected by using the phase difference between III and VI.

In the Figure 6, I is signal vector of a normal part by the forward receiving coils FCn and II is signal vector of the normal part by the rear receiving coils RCn and III is signal vector of the normal part by the

differential wire bound. Since the local flaw part ranges in small area, only the forward receiving coils FCn is included in the flaw area. Considering the case wherein only the signal vector I changes, IV is signal vector of the local flaw part by the forward receiving coils FCn and V is signal vector of the local flaw part by the differential wire bound. The local flaw part FS can be detected by the differential phase between V and III.

Figure 7 illustrates a receiving level by a distance between the exciting coil MC and the forward and the rear receiving coils FCn and RCn. In the drawing, a horizontal axis indicates the differential distance (MC - FCn or RCn) and a vertical axis indicates the signal level. When using the receiving coils having greater number of turns than that of the rear receiving coils RCn to obtain the required receiving level, the number of turns must be increased in order to compensate the decreased level of the receiving level. Therefore, it is apparent from the characteristics view that, when a forward receiving coils FCn having greater number of turns than that of the rear receiving coils RCn are provided forward, a signal level increased by the positioning close to the exciting coil and a signal level increased by the increased number of turns are added to get a stable signal level.

In the above embodiment, number of the forward receiving coils and the rear receiving coil are not limited to six. The receiving coils can be connected in parallel and any number of the coils can be selected. The way of connection between the forward and rear receiving coils FCn and RCn are not limited to the above embodiment, any wiring which can perform the differential operation can obtain the same advantages.

The remote field eddy current sensor according to the present invention has such advantages that more

stable phase data with reference to both of the gradually flaw progressing part and the local flaw part can be obtained in comparison with the prior system.

CLAIMS (DIV.B)

1. A remote field eddy current flaw detector for detecting flaws in a metal pipe, comprising:

a reference signal generator for generating a reference signal;

an exciting coil for receiving an exciting signal having the same phase as that of said reference signal and generating remote field eddy current signals in the metal pipe to be tested;

a receiving coil, spaced axially from said exciting coil by a predetermined axial distance, for receiving said remote field eddy current signals that have passed through said pipe to generate a received signal;

an attenuator for attenuating said exciting signal at a predetermined level;

a phase shifter for delaying the attenuated signal to a predetermined phase angle;

a single adder for adding the attenuated and delayed signal to said received signal; and

a flaw data generator for phase-comparing the added signal generated by said signal adder with said reference signal to generate a flaw signal representative of flaws in the metal pipe.

2. A remote field eddy current flaw detector for metal pipe according to claim 1, further comprising: plural receiving coils wherein each receiving coil is associated with a corresponding attenuator, phase shifter, signal adder and flaw data generator.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report) -19-	Application number GB 9421617.3
Relevant Technical Fields (i) UK Cl (Ed.M) G1N, NCDC, NCDE, NCDL, NCDN (ii) Int Cl (Ed.5) G01N	Search Examiner A J OLDERSHAW Date of completion of Search 28 NOVEMBER 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1,2

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 2129140 A	(ATOMIC ENERGY OF CANADA)	-
A	GB 1403734	(VOLKER DEUTSCH)	-
A	US 4849693	(PRINCE)	-

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).